The ENGLISH ELECTRIC JOURNAL

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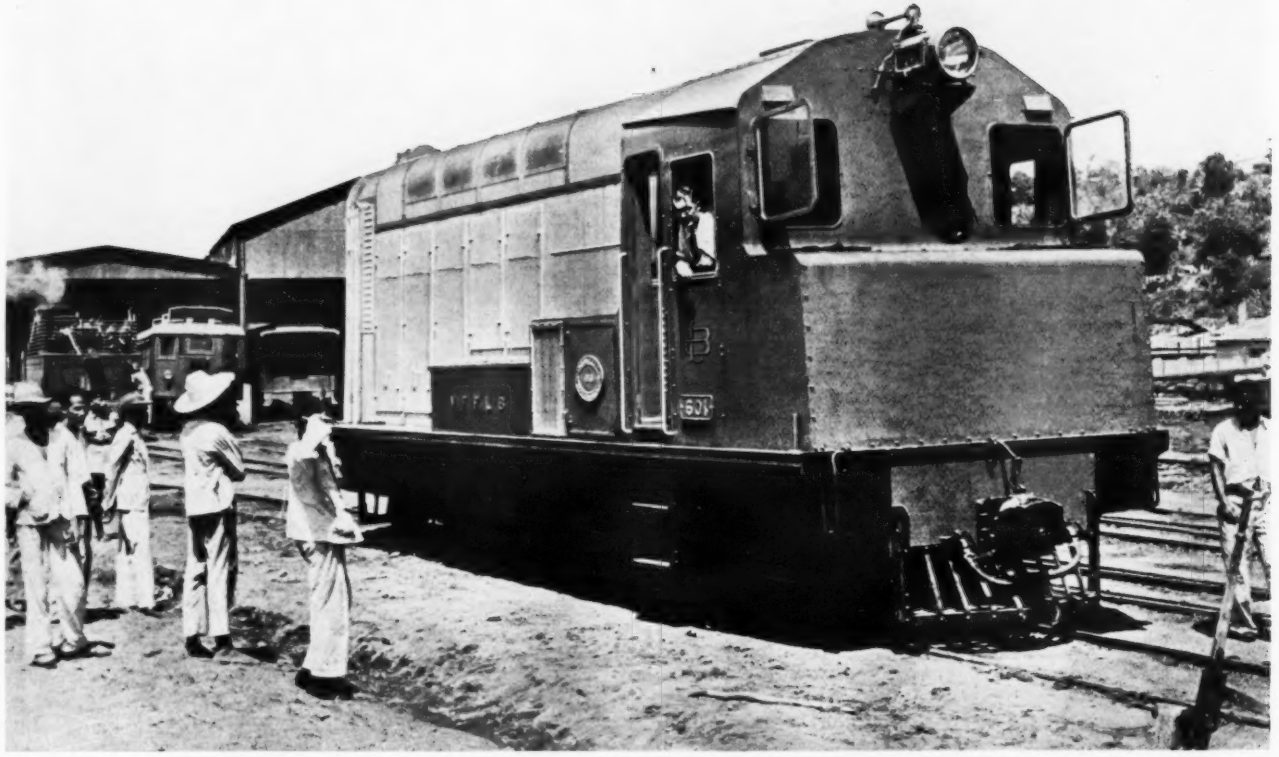


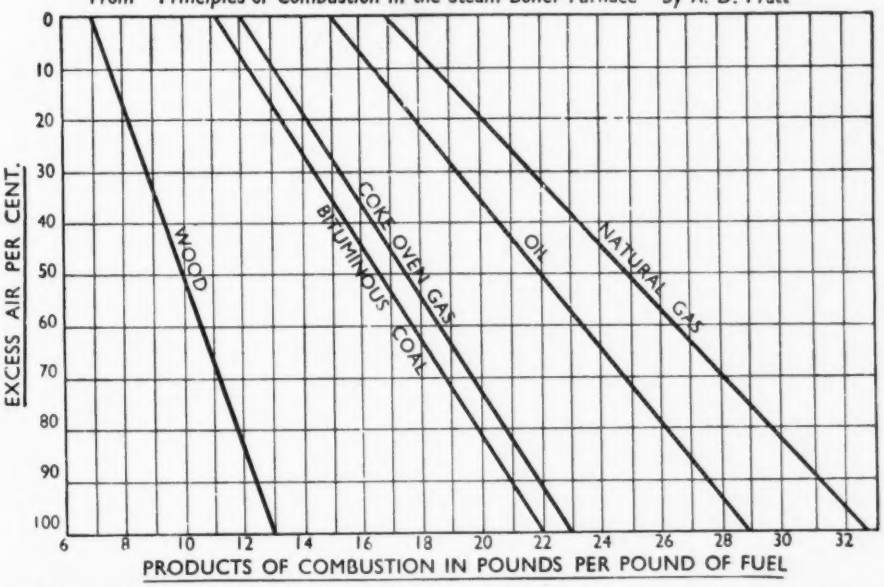
Diesel-Electric Locomotive for Eastern Railways of Brazil fitted with "English Electric" type 8K–470 h.p. engine.

EXCESS AIR – PER CENT

What does CO_2 mean?

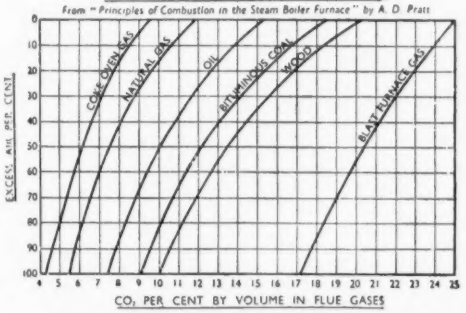
Relation Between Excess Air and Products of Combustion

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



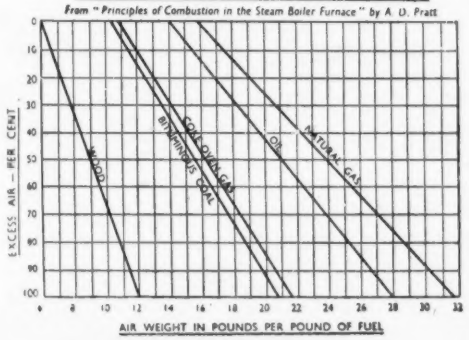
Relation Between Excess Air and CO_2

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



Relation Between Excess Air and Air Weight

From "Principles of Combustion in the Steam Boiler Furnace" by A. D. Pratt



This is the third of a series of three advertisements.

FROM the above chart it will be seen that when burning 1 lb. of coal, an increase from 20% to 100% excess air means that the weight of the products of combustion is increased by approximately 8½ lb.

Our previous advertisement showed that this increase in excess air involved an increase in the weight of air for combustion by the same amount. Thus the forced draught and the induced draught fans together must handle approximately 17 lb. more air and products of combustion than that necessary for efficient combustion.

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Criticism might be made that the limits are too wide in the foregoing example, but even if operation is assumed with 60% excess air, then the unnecessary fan power expenditure is £2,840 per annum, which when capitalised amounts to £84,570. However, when it is realised that this fan power debit is one of the smallest items entering into the balance sheet, it will be obvious that Bailey furnace construction is in the last analysis the cheapest construction which can be installed.

(For convenience we reproduce the charts from our Nos. 1 and 2 advertisements in this series, showing the relationship between excess air and CO_2 and weight of air for combustion.)

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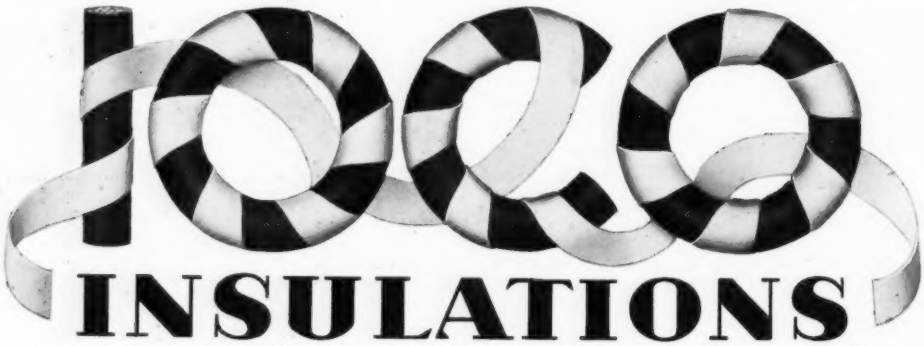

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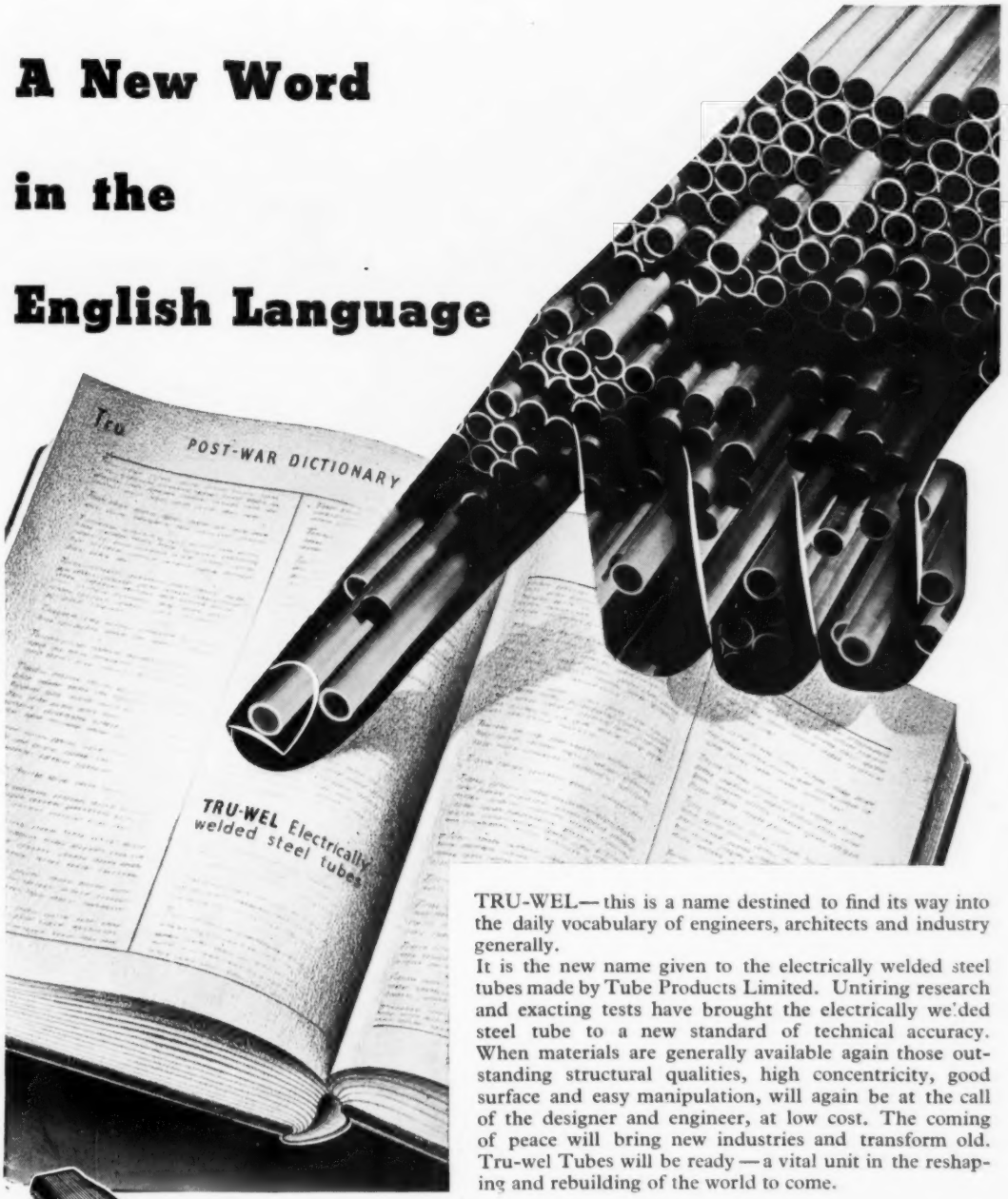

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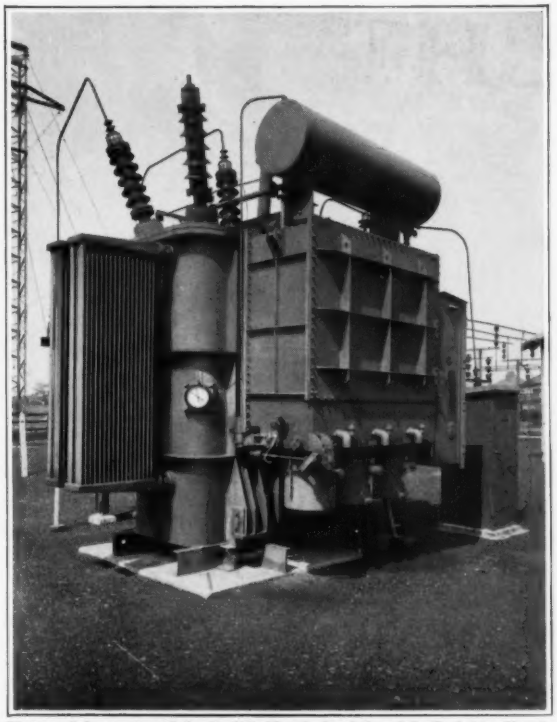

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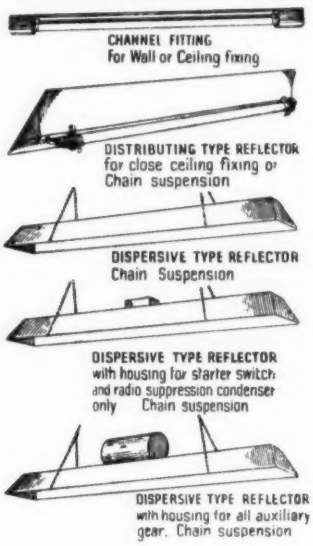

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The English Electric Journal

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CONTENTS.

PAGE

DIESEL-ELECTRIC SHUNTING LOCOMOTIVES - - - - 98

A 500 KW. QUICK-STARTING STEAM TURBINE UNIT FOR EMERGENCY USE - - - 102

STREAMLINE DIFFUSING DISCHARGE REGULATORS - - 107

THE USE OF NOMOGRAMS IN ENGINEERING DESIGN - - 113

All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, THE ENGLISH ELECTRIC COMPANY LIMITED, STAFFORD.

EDITORIAL.

In April of this year Mr. C. E. Fairburn, Deputy Chief Mechanical Engineer and Electrical Engineer of the London Midland and Scottish Railway Company, read before the Institution of Locomotive Engineers a Paper on Diesel Shunting Locomotives, and by the courtesy of Mr. Fairburn and of the Institution, we are able in the first article in this issue to publish some extracts from the Paper. The L.M.S. Railway Company have had operating experience on such locomotives extending over several years, and hence the information given by Mr. Fairburn is of unusual interest. Until now operating data on this subject has been obtainable only from foreign sources, where conditions are often quite dissimilar from those in this country.

Much of the data published in the Paper relates to the operating results of loco-

motives with " English Electric " engines and electrical gear. The L.M.S. Company have a number of these locomotives in service.

In the second article Mr. J. T. Moore describes a 500 kW quick-starting Turbine unit for emergency use which the English Electric Company have supplied for a large power station overseas. In this country, in normal times, the need for house and emergency sets had decreased, owing to the interconnection of power stations via the Grid, but in present-day conditions occasion may arise when an outside supply is not available for re-starting after a complete shut-down and a special emergency unit may be of great service. Such sets can be arranged to run up to speed automatically on the failure of the supply, or by means of remote control from the main control room.

It is to be noted that during tests at the Company's Works the set described ran up to speed and was under the control of the turbine governor in the remarkably short time of thirty-six seconds.

In the third article Mr. H. L. Bazalgette describes the " English Electric " Streamline Diffusing Discharge Regulator. With this regulator large quantities of water can be discharged from storage reservoirs and the like without danger of erosion of the bed of the river or channel into which the water is discharged. The article deals with the action of the regulator, its construction and the various methods of operation and is accompanied by a number of illustrations showing the regulator in operation on dams overseas.

" Nomograms in Engineering," by Mr. L. C. Hookins, are the subject of our concluding article. They are extremely useful for the rapid solution of frequently-used formulae, and particularly of those containing more than two variables. The author explains the construction and use of nomograms of this type by means of practical examples. A number of charts for the solution of various formulae are reproduced.

Diesel-Electric Shunting Locomotives.

Extract of Paper read before the Institution of Locomotive Engineers, 30th April, 1941, by C. E. Fairburn, M.A., M.I.Loco.E., Deputy Chief Mechanical Engineer and Electrical Engineer, London Midland and Scottish Railway Company.

(With notes by H. H. Andrews, M.I.Loco.E., Assistant Manager, Traction Department, The English Electric Company, Ltd.)

The use of Diesel-electric propulsion on British Railways is almost entirely confined at present to shunting operations. It is characteristic that British Railways have elected to obtain their first experience of this type of drive by operation in a service for which it presents many natural advantages. Operation has now taken place over a period of several years and data on performance and maintenance is commencing to accumulate. Whilst at the moment every British Railway has in operation or under construction Diesel-electric shunters, in varying quantities, the L.M.S.R. alone has made very considerable development in this connection. Following on experiments which started in 1931 with 8 different types of mechanical transmission, which did not fulfil the required services, two Diesel-electric units were put into operation in 1934. As a result of the experience gained with these, 20 more went into operation in 1936, an additional 20 in 1939, and a further 20 are now on the point of completion. The Railway has, therefore, available operating data for a considerable number of Diesel-electric shunters for periods varying from two to five years, apart from the experimental locomotives.

Of the locomotives mentioned, one of the 1934 class, ten of the 1936 class and all the succeeding locomotives are equipped with " English Electric " 350 H.P. Diesel engines and electrical equipment. The operational data collected by the L.M.S.R. is of the first importance and was made available to Engineers in the Paper read by Mr. C. E. Fairburn, Deputy Chief Mechanical Engineer and Electrical Engineer of the Railway before the Institution of Locomotive Engineers on April 30th, 1941. By the courtesy of Mr. Fairburn and the Institution, we are permitted to reproduce extracts from the Paper.

Shunting locomotives have to undertake a variety of duties according to the use on which they are employed, but to ensure general availability they are all built to a specification which enables them to operate on the most arduous services. The following extract from Mr. Fairburn's Paper gives a picture of the work in a heavy duty yard :—

" With the completion of over 40 Diesel-electric locomotives it became possible to assess their performance with reasonable accuracy. Attempts were made, as far as possible, to concentrate them at a few yards where continuous shifts were in operation. This made it possible to take full advantage of their availability and to place their maintenance on an adequate basis without employing a large special staff.

" Perhaps the most interesting use is that made at the Toton Down sidings which have recently been mechanised. The lines there are shown on a single line diagram in Fig. 1. Trains, largely of empty mineral wagons, are broken up as they pass over the hump, and the wagons, either singly or in small groups, run by gravity on to one of the lines of one of the four ' fans ' of sidings.

" According to the wagons' destination the King, Queen and Jack points are set electrically

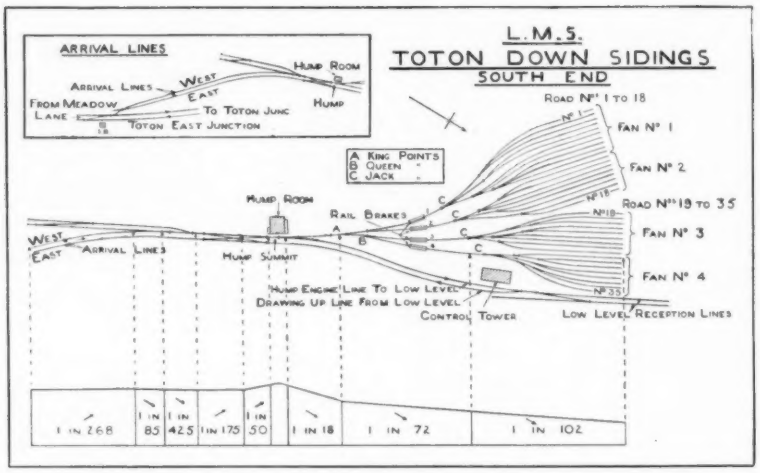


Fig. 1.—Layout of Toton Down Sidings, L.M.S. Railway.

from the hump room and the siding points are similarly set from the Control Tower. The four rail brakes between the Queen and Jack points which control the speed of the wagons, are also operated from the Control Tower. The co-ordination between the various operations is effected by a loud-speaker system, and there is a special form of teleprinter operating between the hump room and the Control Tower to give the destination of the wagons. Normally there are six Diesels stationed at Toton and these deal with all the work on the down sidings, also with a non-mechanised hump on the up sidings and with certain ordinary shunting duties. They are usually in service for 18 shifts of eight hours per week. One shift is sufficient for the normal weekly examination of a locomotive."

It will be noted that 18 shifts of 8 hours per week represent six days continuous working, with one day off, so that the working factor is 85.7 per cent. While this figure is satisfactory, it does not represent the full availability of the Diesel-electric shunter, as will be seen from the following quotation :—

" As an example of the results obtained, the following figures have been compiled from records taken at Toton where the use of Diesel locomotives has already been mentioned. Of the six units stationed there, one is regarded as a spare. This gives a higher ratio of spare to service locomotives than is necessary, and somewhat better figures would be obtained if a larger number of units were in use there.

" Over a period of twelve months the average number of hours each locomotive has been in service represents 70 per cent. of that period, viz., 8,760 hours. The locomotives were actually available for service for 87 per cent. of the period. The theoretical technical availability on the basis of the maintenance procedure then in force was 93 per cent. On the basis of the revised maintenance procedure now adopted the theoretical technical availability will be 96 per cent.

" The difference between the theoretical and the actual technical availability is due to withdrawals from service owing to breakdown and to delays in completing overhauls.

" Despite additional costs incurred due to the introduction of the Diesel on to a steam system and to the necessity for building up an organisation to deal with relatively small numbers of a new type of machine, Diesel locomotives have justified themselves financially in the particular intensive services where they have been used."

The question that is most frequently asked about Diesel-electric equipment is : " What is the cost of maintenance ? " It is no real satisfaction either to a prospective user or to the manufacturer to provide theoretical figures of life and cost of maintenance, and only an operator such as the L.M.S.R. can collect and publish data in sufficient detail over a long period which can be considered as reliable. Mr. Fairburn's statement on this subject should therefore be of special importance.

" Locomotive maintenance is divided into work consisting largely of periodical examinations carried out at the running sheds and main over-

hauls carried out at a principal works. In both cases the procedure centres round the Diesel engine itself.

" The Jackshaft, coupling rods, axleboxes, etc., are items with which the Railway Company is familiar and their maintenance entails no difficulties and little expense.

" The electric transmission equipment is similarly familiar and its maintenance follows lines laid down for electric equipment on rolling stock. The brush gear and commutators of the generator and motor require only infrequent inspection. The control gear is simple and there are few contacts which break current, although they may do this a large number of times during a day's work. The equipment has given little trouble as, indeed, should be the case.

" The engine, however, may be running almost continuously throughout the week, and though the actual distance covered by a locomotive may be only about 30 miles per day, the engine may make 500,000 revolutions during this time. For only a very small part of this time is full load demanded and the average h.p. may be only about 30 per cent. of the full rated load. But the load and the speed of the engine are varying continuously and rapidly and such service is more severe than steady running at higher load and speed.

" Appendix II gives the present maintenance schedule for the mechanical and electrical equipment. There is no doubt that many of the periods could be considerably extended and this is being done gradually where experience shows that it is safe to do so, but it will be appreciated that it is better in a new venture of this kind to be on the safe side.

" APPENDIX II.

" *Maintenance Schedule.*

" Daily Maintenance.—The driver is responsible for superficial examination, checking oil levels, operation of sanding gear, etc., and lubricating the motion.

" Running Shed Maintenance.—This is divided into two sections :—(*a*) Electric equipment under the C.M.E. and E.E. Department ; (*b*) Mechanical equipment under the Motive Power Department.

" Electric equipment maintenance comprises :—

" 1. Fortnightly examination, cleaning and lubrication of controls, relays, contactors,

Fig. 2.—L.M.S. Railway Diesel-electric Locomotive.

engine change speed gear, and dead man's treadle. Battery pilot cells are examined and the battery topped up when necessary.

" 2. An 800-1,000 mile examination of motor and generator brush gear and commutators, checking of tightness of terminals, etc., and blowing out machine windings. Lead acid batteries are cleaned and greased and specific gravities recorded. Alkaline batteries are examined and greased.

" 3. A 2,400-3,000 mile greasing of motor and generator bearings.

" Mechanical maintenance comprises :—

" 1. Weekly making-up of oil levels in fuel tanks, engine, air compressor and exhauster sumps. Filling of grease cups, checking of engine lubricating system. General examination of locomotive and auxiliaries and adjustment when necessary of engine valve gear and locomotive brake gear. Draining of water from air reservoirs, and filling up of engine cooling system, cleaning of lubricating oil filters.

" 2. An 800-1,000 mile checking of valve clearances, examination of main and big-end bearings, checking of oil flow from bearings and examination of lubricating oil pipes, testing of fuel injectors and greasing of nipples on brake gear and locomotive auxiliaries

" 3. A 2,400-3,000 mile examination of camshaft bearings, valve operating gear, including its lubrication system, road wheels and tyres. Removal of caged exhaust valves and re-grinding. Draining, cleaning and refilling of engine sump, lubrication of air brake cylinders.

" 4. A 4,800-6,000 mile examination of engine auxiliary chain drives, removal and re-grinding if necessary of inlet valves. Checking of crankshaft alignment. Draining and refilling of compressor and exhauster sumps. Examination of side rod bearings and locomotive drawgear. Examination and cleaning of air valves in dead man's device.

" NOTE.—Mileage figures throughout the Paper are actual miles as recorded by a milometer fitted to each locomotive.

" Careful measurements of wear are being taken. Fig 3 shows results obtained with cylinder liners. It has not yet been possible to establish average quantitative results. It must be appreciated that there are several variables which affect rates of wear. These variables, the influence of which has not yet been determined, are the materials of the liners, pistons and rings, the composition of the lubricating oil, the means of maintaining the purity of the oil, etc. Similar measurements are being taken of wear on other parts of the Diesel engines.

" General overhauls are at present made at intervals of about 15,000 miles; this will shortly be increased, probably to 20,000 miles or more. The amount of work done at each overhaul depends upon the condition of the locomotive and particularly of the engine. All wearing surfaces are examined, alignments checked, etc., and when the locomotive is returned to service it is in practically new condition. In judging the state of the engine the crankshaft alignment is taken as the most important single indication and it largely determines whether or not the engine generator unit is

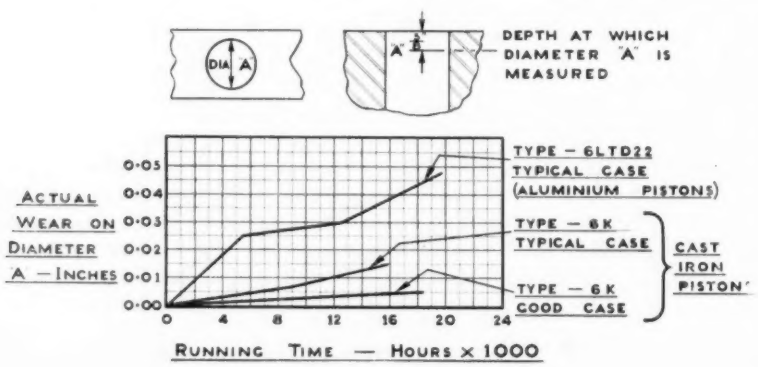


Fig. 3.—Graph showing cylinder liner wear.

removed from the locomotive frame. An increase in liner diameter of 0.040 in. is allowed before the liner is replaced."

In dealing with the period between overhauls and the various periods between examinations all the references have been given in miles. To appreciate what this means, it is necessary to keep in mind the very low average speed of shunting operations. It has been railway practice to take these operations at a statutory 5 m.p.h. basis when making up annual returns, but it is common knowledge that this is far higher than the true figure. The records taken on the Diesel shunters show that they work on an all-in figure of 1¼ m.p.h. This is not a figure peculiar to the Diesel shunters and as Mr. Fairburn pointed out in the discussion following his Paper it also represented the average speed of the steam shunters.

Translating the mileage figures into hours, 1,000 miles represents 800 hours or 33⅓ days, so that 20,000 miles between overhauls means a service of 666 working days or approximately 2 years in total time.

The strong probability that this figure will be considerably extended gives a fair indication of the reliability and low maintenance costs of the Diesel-electric shunting locomotive.

A 500 kW. Quick-Starting Steam Turbine Unit for Emergency Use.

By J. T. MOORE, B.Sc., A.R.T.C., A.M.Inst.C.E., A.M.I.Mar.E., Steam Turbine Department

Before the interconnection of steam power stations under the "Grid" System, it was necessary in all stations to have some form of emergency power supply to auxiliaries for use when starting up or getting away again as soon as possible after a complete shut-down. In most cases this took the form of a small house-unit which could be started up on both the boiler and turbine sides without any auxiliary electrical power, and thus supply the power for essential auxiliaries to raise and maintain sufficient head of steam to run up one of the larger sets in the station. In other cases one of the smaller sets in the station which might otherwise have been taken out was retained and adapted to serve as a house-set in emergency, as under such conditions its efficiency was not of great importance, and an old machine suitably modified served the purpose well. Such sets were generally started up non-condensing to supply essential auxiliaries, and later changed over to condensing operation when cooling water supplies became available.

With the interconnection of power stations, there was made available, under normal circumstances, an alternative or outside source of power for starting up auxiliaries even when the station had been completely shut down, and in most large stations it is now common practice to keep a proportion of the auxiliaries running from the outside supply. This reduces the possibilities of an unintentional shut-down, while if the station has to be started up from a complete shut-down, the external source of power makes this a simple matter.

The need for house-sets and emergency sets has, therefore, decreased very much in stations interconnected with other sources of supply, more especially as many stations can link up permanently, or reasonably quickly in case of need, with a second external supply. The occasion may arise, however, where a total shut-down takes place in a station and, possibly as a result of the shut-down, no power is obtainable from any outside source. To start up a turbo set under such conditions means the raising of a head of steam in a boiler without any auxiliary power, and the running up on atmosphere, in

most cases, of one of the smaller sets in the station to obtain sufficient power for the boiler fans and stokers, and the condenser pumps. While in the majority of stations containing a proportion of older, and as a rule small units, this is generally possible in order to put into service one of the larger units, the modern station with only large units is faced with the possibility of not being able with safety to start up from a total shut-down without an external power supply for auxiliaries. Such stations must accordingly have some form of emergency unit to take care of such a contingency.

The larger the station, the greater is the need for preventing an involuntary total shut-down, and if this should occur with a simultaneous removal of all outside sources of supply, still greater is the necessity for getting the plant back into service with the minimum loss of time. In the smaller stations, on the other hand, there is not the same necessity, relatively, for getting away again immediately and the longer time required to start up one of the small sets in the station is generally not so serious.

For these reasons, the provision of special emergency units is confined mainly to the larger stations in this country, to stations at one end of a long supply line, or to stations not interconnected with other stations, as happens more often abroad.

High thermal efficiency not being of first importance, steam emergency units for the purposes outlined are generally designed for exhausting to atmosphere in order to obtain quick starting. In some cases the control is so arranged that the unit is run up to speed automatically on failure of the main supply to the auxiliaries on the boilers and turbines, or as in the majority of cases, the unit is arranged to be started up by means of remote control from the main control room or from any other suitable control point. Equally, oil engine driven units can be arranged for emergency use in a similar manner, and a number of both types have been supplied by the Company for use in large power stations both in this country and overseas.

An emergency quick-starting turbo set of the type referred to, and illustrated in Fig. 1, was supplied in 1935 for a station in this country, which was located at the end of a long supply

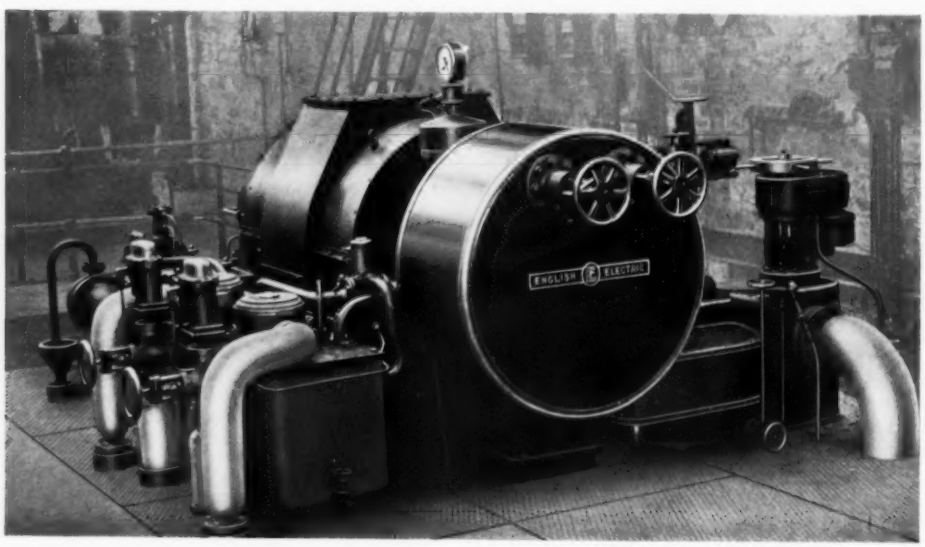


Fig. 1.—300 kW., 3,000 r.p.m. quick-starting emergency Turbo-alternator Set.

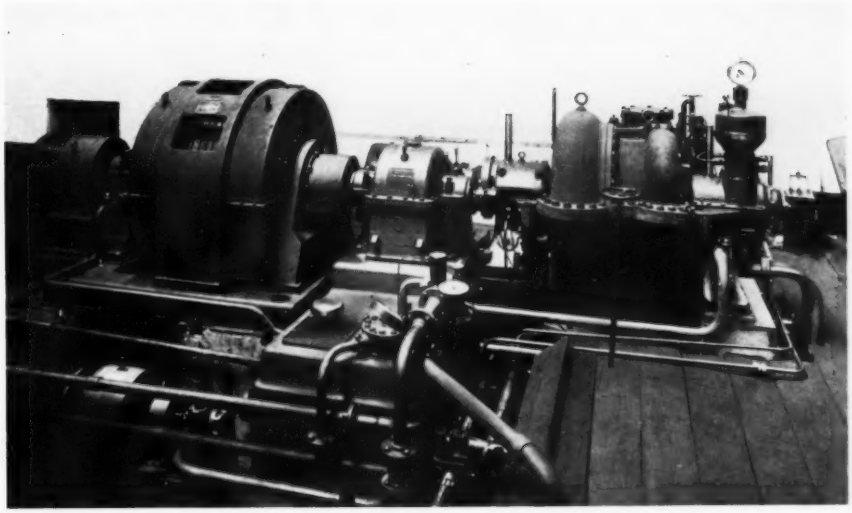


Fig. 2.—500 kW., 6,000/1,500 r.p.m. quick-starting emergency Turbo-alternator Set on test at the Company's Works.

line. The unit, of 300 kW. capacity, was arranged for automatic starting in the event of a failure of the supply to the main auxiliaries in the station. The set comprised simply a 3,000 r.p.m. alternator with extended shaft-end on which was mounted, overhung, a velocity compounded turbine wheel. Designed for exhausting to atmosphere, the turbine was very suitable for quick starting, and in service it was found that it could be run up to speed in a matter of 30 seconds.

More recently the Company have completed the manufacture and testing of a 500 kW. emergency quick-starting unit for a large power station overseas where there was no interconnection with external sources of supply. Although this station contains a number of comparatively small turbo-sets, one of which in emergency could have been started up without power for its auxiliaries, the time which this operation would have required in the event of a total shut-down might have had serious consequences in the process plant associated with the station. For this reason it was essential to reduce to a minimum the period of any inadvertent total shut-down, and the new 500 kW. emergency unit has been designed specially for entirely automatic operation by remote control, and for running up to full speed in the shortest possible time.

Fig. 2 illustrates the turbo-set on test at works before despatch, complete with its accessory equipment. The turbine, of the impulse type, is designed to take steam at a pressure of up to 200 lb./sq. in. and 750 deg. F. total temperature, and runs at a speed of 6,000 r.p.m. driving the alternator, through reduction gearing, at a speed of 1,500 r.p.m. The alternator, of the salient pole type, is designed for a three-phase, 50-cycle supply, and is complete with exciter mounted overhung on the extended alternator shaft. A flexible coupling is provided between turbine and gear pinion, but the alternator rotor is solidly coupled to the slow-speed gear wheel, the weight of the rotor being shared between the main gear bearing and the alternator outboard bearing. The turbine being of the impulse type, with only one velocity compounded stage as shown in Fig. 3, large blade clearances can be allowed without undue sacrifice of efficiency and, with all high steam pressures and temperatures confined to the nozzle belt before the main nozzles, the unit is particularly suited for quick starting without distortion of the turbine casing and consequent mis-alignment troubles. The turbine shaft glands, of the

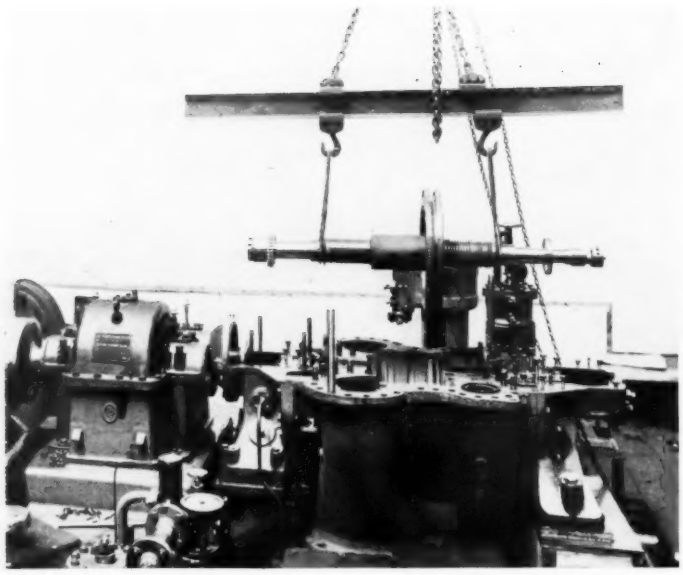


Fig. 3.—500 kW., quick-starting emergency Turbo-alternator Set with the top half turbine casing removed and showing design of turbine rotor.

labyrinth type in which there are no rubbing parts, are fitted with a small steam jet ejector which comes into operation automatically on the main steam valves opening. The ejector withdraws the leakage steam from the glands and discharges to the turbine exhaust branch, thus avoiding any leakage of gland steam into the engine-room. Apart, therefore, from the closing of drain valves once the turbine is up to normal temperature and the routine inspection of bearing temperatures, etc., the unit requires no attention in service.

Starting is effected by remote control from a special panel in the main control room. The small amount of auxiliary power required for starting is provided from the station storage battery system, but in the unlikely event of even this supply being unavailable, the unit can still be started up by hand from the turbine platform by using the steam-driven auxiliary oil pump provided to cover such a contingency.

The complete control system is shown in Fig. 4 from which it will be noted that control of the various sequences of operations is effected by oil under pressure supplied, in normal circumstances, from a motor-driven oil pump on starting up, and maintained, when the unit is up to speed, by the main gear oil pump driven from the turbine shaft. The panel in the main control room contains, in addition to an electrical speed indicator actuated from a tachometer generator on the turbine, the starting switch for the motor-driven oil pump, with three positions marked " Hand," " Off " and " Auto," and a red and a green signal lamp.

On starting, the main steam and cooling water isolating valves on the set being always open, the motor switch is turned to the " Hand " position. The pump starts up, the red signal lamp lights up and as soon as the oil pressure has built up sufficiently high, the pressure commences to lift the oil-pressure controlled emergency stop valve and the main throttle valve controlling the supply of steam to the turbine. At the same time the oil pressure opens an oil-pressure controlled water-admission valve to the oil cooler. The turbine begins to turn as soon as the steam emergency and throttle valves leave their seats and full speed is reached within about half a minute from the motor-driven oil pump starting up. When full speed has been attained the turbine governor takes control and maintains the speed constant. The speed of the set, should it be necessary, can be adjusted by remote control of the governor speedermotor, and in the same way the unit can be paralleled with any supply available later.

When the turbine is running steadily under the control of the governor, the switch of the motor-driven pump is turned through the " Off " position to " Auto," when, providing the main gear oil pump driven from the turbine is functioning properly, the motor-driven pump shuts down, the red signal lamp is extinguished, and the

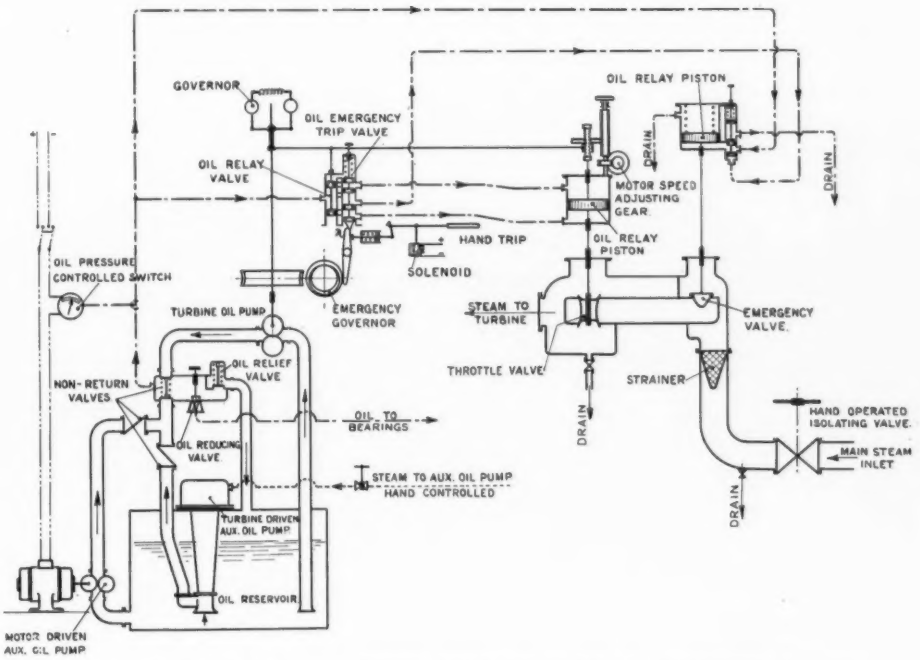


Fig. 4.—Diagram of oil-pressure operated control gear on 500 kW., quick-starting emergency Turbo-alternator set.

green lamp lights up. The motor-driven oil pump is then in a position to start up automatically should the relay oil pressure fall below normal.

In normal circumstances the steam-driven oil pump provided as standby is isolated from the main steam supply and therefore inoperative, but, with hand control, it can be used for starting and when stopping the set, should the motor-driven oil pump be out of service or fail to function when required.

For shutting down the set from the control panel, a " Stop " button is provided which causes a solenoid fitted to the turbine emergency trip to be energised and thus trips the set. Equally the emergency trip can be operated by hand from the turbine platform.

Before despatch from works the set with its control equipment, oil pumps, etc., was erected and tested under its designed steam conditions, and numerous tests of starting up periods have been averaged in the curve shown in Fig. 5.

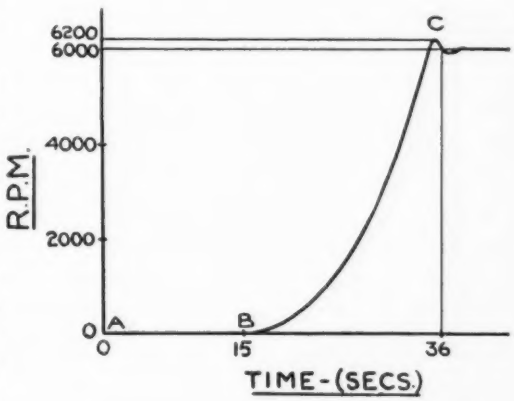


Fig. 5.—Speed-Time Curve on starting 500 kW. quick-starting Emergency Turbo-alternator Set.

A.—Motor-driven oil pump started up.

B.—Main steam control valves commence to open.

C.—Main turbine governor takes control.

From the moment of starting the motor-driven oil pump, about fifteen seconds was required for the pump to generate sufficient pressure to open the main steam control valves, and the unit was up to speed and under the control of the turbine governor within the remarkably short time of thirty-six seconds. Even under such onerous starting conditions, the balance and running of the set was very satisfactory.

The provision of such quick-starting emergency units in large stations is well justified under peace-time conditions, but under the more exacting conditions of to-day, their value cannot be over-emphasised.

Streamline Diffusing Discharge Regulators.

By H. L. BAZALGETTE, A.C.G.I., A.M.Inst.C.E., A.M.I.E.E.

Fig. 1.—"English Electric" Discharge Regulator in operation on a Dam in Australia.

The problem of destroying the harmful energy in powerful streams of water has exercised the minds of engineers for many years and the English Electric Company can claim to be pioneers in its solution since they supplied streamline diffusing discharge regulators of their design as long ago as 1924.

As designers and manufacturers of water turbines the Company have had much experience in the construction of the turbine relief valve, the primary purpose of which is to discharge large quantities of water into the tailrace without endangering the Power House foundations, and for this duty a design was evolved and patented by which the energy of the jet was destroyed by transforming it into a hollow cone as it leaves the discharge regulator.

It was but a short step to adapt this same

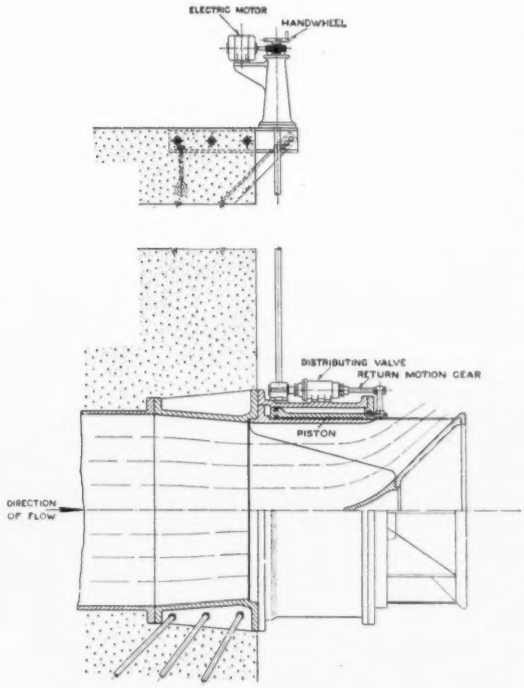


Fig. 2.—Hydraulically operated Streamline Diffusing Discharge Regulator.

principle to the discharge of water from storage reservoirs or wherever it is necessary to regulate with safety the outflow of water past a dam.

Action of the Discharge Regulator.

The Regulator consists of two concentric cylinders and a streamline dispersing cone which is attached to the inner cylinder by radial webs. The outer cylinder or piston slides on the inner cylinder and closes the space between the latter and the cone. This construction is illustrated in Fig. 2 and also in Fig. 3, which shows a shop assembly of the regulator in a partially open position. When open the water is diverted by the streamlined dispersing member and is automatically discharged in the form of a hollow divergent cone which spreads over a rapidly increasing area. Thus its effective energy is quickly dissipated by air friction and disintegration, and the whole of the discharged water descends in a form which can be likened to a heavy rain shower. Pressures are virtually balanced with the result that there is no tendency to slam shut and only a small amount of power is required for operation These advantages are produced by the fact that the outer cylinder, which regulates the water flow, is in perfect balance from radial pressure and the axial thrust on this cylinder is very small since the only area under this pressure takes the form of a thin ring. Hence the regulating cylinder moves steadily under a light force and the streamline form of dispersing cone ensures maximum discharge capacity and effective diffusing action at any opening. A small force suffices to keep the cylinder tightly closed against the fixed seating ring.

Construction.

It is usual to make the regulating cylinder or piston and the seating ring of stainless steel, and the main body of cast steel or cast iron, according to its size and the head to be catered for. The strips attached to the barrel and ribs, on which the cylinder slides, are made of rustless material. Fig. 4 shows a typical cross section through a dam and illustrates the method of installing the

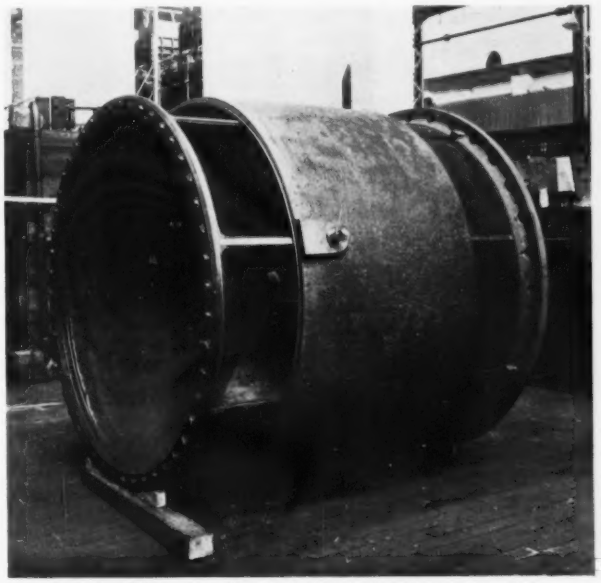


Fig. 3.—Shop assembly of Cylindrical Balanced Regulator.

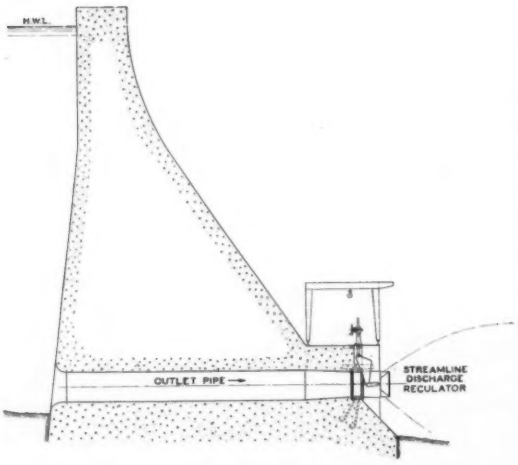


Fig. 4.—Cross Section through a Dam showing method of installing an "English Electric" Streamline Discharge Regulator.

discharge regulator; the inner body is rigidly bolted to the downstream section of the outlet pipe which is buried in the face of the dam.

The whole regulator, or any of its component parts, can be easily removed by lifting tackle located on a control platform and it may be emphasised that the weight and number of the component parts is less than with any other type of discharge regulator.

Methods of Operation.

The discharge regulator can be either hydraulically, electrically or mechanically hand-operated. In the case of hydraulic operation, the regulator is surrounded by an outer casing of cast steel or cast iron which forms the servomotor chamber and operates the cylindrical piston. Sealing of the servomotor chamber is effected by vulcanised rubber pads of standard cross section and these are kept against their working surfaces by water pressure and leakage past the piston is thus prevented.

The control gear is mounted on the outer casing and consists of a distribution valve with return motion or compensating gear which prevents creeping of the piston and enables it to be held at any desired opening. Thus if the piston moves even to the slightest extent water is admitted to the servomotor, the motion is arrested, and the piston is returned to its original position.

In normal cases the regulator is operated by a handwheel but an electric motor can be substituted when desired in order to give remote control. In the latter case control is sometimes effected by means of a float which rises or falls with the reservoir level. Fig. 2 shows a regulator for hydraulic operation with distribution valve and servomotor and alternative control by handwheel or electric motor.

The mechanically hand-operated regulator is illustrated in Fig. 5 and is a very simple piece of mechanism. The cylindrical piston is provided with two external bosses for connection to the operating gear and sealing is effected by a rubber ring or pad which prevents leakage between the cylinder and the main body.

The handwheel actuates, through gearing, a forked lever which is rigidly pivoted and linked to

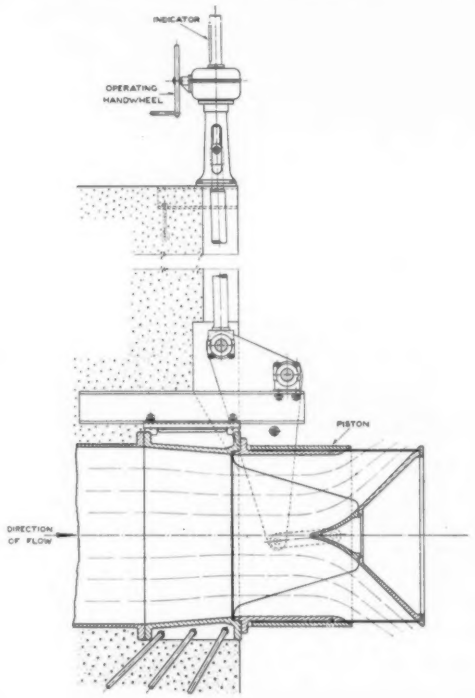


Fig. 5.—Sketch of a Hand-operated Discharge Regulator.

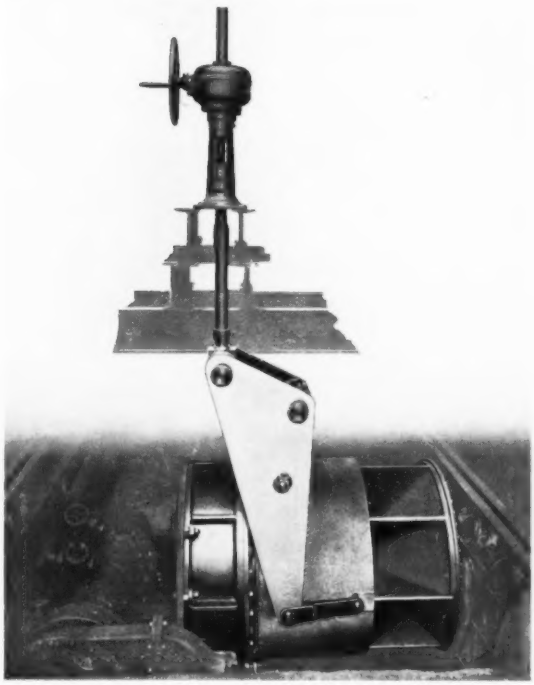


Fig. 6.—Shop Assembly of Hand-operated Discharge Regulator.

the piston. Owing to the fact, already mentioned, that pressures are virtually balanced only a small amount of power is required for operation and the hand-control gear provides a large reserve to meet all conditions of closing and to force home the piston against its seat. The gearing is non-reversible so that the piston will remain at any desired opening.

A shop assembly of a hand-operated discharge regulator is shown in Fig. 6 and the operating handwheel can be placed in any convenient position.

Advantages.

The "English Electric" Discharge Regulator possesses very considerable advantages which may be summarised as follows :—

(1) *Low Initial Cost.*—The compact and simple design of the discharge regulator, requiring no elaborate concrete or masonry, results in a low first cost. A plain anchor block at the end of the discharge pipe is all that is necessary to keep the regulator in position.

(2) *Durability and Low Maintenance Cost.*—By using the best quality of material and workmanship, durability is ensured, and maintenance costs are reduced by making the sliding surfaces of stainless material. Thus rusting up is impossible in continuous operation or during long periods of shut-down.

(3) *Ease of Dismantling.*—The discharge regulator or any of its component parts can be readily removed by lifting tackle on the control platform and, as already pointed out, the number and weight of the parts compare very favourably with any other type of regulator.

(4) *Absence of Erosion.*—The danger of erosion of the bed of the river or channel into which the water is discharged is eliminated by the complete dispersion of its energy at every degree of opening.

(5) *No Chattering.*—The short water path through the discharge regulator together with smooth streamline flow at all openings gives the maximum discharge capacity for the minimum dimensions and the complete absence of chattering is ensured.

(6) *Balanced Closing Cylinder.*—The balanced closing-piston or cylinder operates smoothly and will close the valve under all conditions because it is free from distortion, and is guided over the whole stroke by the cylinder and ribs of the inner body and moreover can be moved by light forces.

(7) *Operating Gear.*—The operating gear is entirely external to the regulator and can, therefore, be inspected without dismantling the latter. Both servomotor and handgear have an ample reserve of power which ensures perfect regulation at any opening as well as dealing with any emergency.

Examples in Operation.

The Company have many examples of their turbine relief valve and discharge regulator in successful operation, and two of the latter are illustrated in this article.

Fig. 7.—Discharge Regulator partially open.

Fig. 8.—Discharge Regulator fully open

Fig. 1 shows a general view of a 7 ft. 6 in. diameter discharge regulator in operation on a large dam in Australia. This regulator is located at the end of a 9 ft. diameter pipeline traversing the dam and passes 3,000 cubic feet of water per second under the highest head of 165 feet and 1,860 cubic feet per second under the lowest head of 63 feet. It is hydraulically operated and in service the piston has proved remarkably steady, retaining any degree of opening indefinitely.

Figs. 7 and 8 are further views of this regulator in operation, the former showing the water stream when the regulator is partially open and the latter when fully open. In Fig. 7 the scale can be judged by the man standing on the top of the anchor block. A large part of this regulator was manufactured in Australia to the Company's designs by the Clyde Engineering Company and has been so satisfactory in service that a duplicate valve for the second pipeline was subsequently ordered. Another interesting example of an "English Electric" discharge regulator is shown in Figs. 9 and 10. These illustrate a 5 ft. diameter regulator installed on a dam in New Zealand and designed for heads varying from 102 ft. to 22.5 ft. Fig. 9 gives a general view of the regulator discharging from the face of the dam, the hand regulating column can also be seen, whilst Fig. 10 shows very clearly the form and dispersion of the jet.

Fig. 9.—"English Electric" Discharge Regulator in Operation in New Zealand.

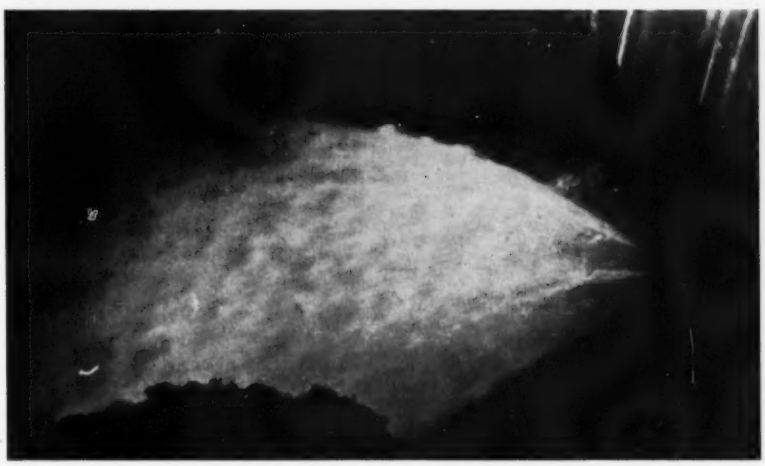


Fig. 10.—Spreading discharge of a Diffusing Discharge Regulator.

The Use of Nomograms in Engineering Design.

By L. C. HOOKINS, A.M.I.Mech.E., Steam Turbine Department.

The use of curves plotted in cartesian co-ordinates is often resorted to for the rapid solution of frequently-used formulæ, and this method—widely used to save time in engineering practice—serves the purpose admirably in cases where only two variables are concerned. As the number of variables increases, however, such curves tend to become highly complicated and often prove cumbersome in use. In many of these cases nomograms, or alignment charts, will be found to be much more convenient.

Although the principle of nomograms is well known, the application of these time-saving aids in drawing and design offices does not seem to be as common as might be expected. Not only do they save time, but, where the formulæ to be solved involve the somewhat tedious evaluation of various powers or roots, mistakes are less likely if nomograms are used. A case in point is that of spring calculations where, owing to the number of variables, the preliminary design usually entails several tentative attempts until a satisfactory balance between space available and spring stresses has been established. A suitable nomogram enables such trials to be made in a matter of seconds, and moreover with as near an approach to immunity from error as is humanly possible.

The literature on the subject, while fairly extensive, in many cases does not go into practical detail, and a few examples of these charts which have proved useful in the Company's Steam Turbine Design Office, together with brief instructions for the construction of several typical specimens, will enable engineers who have not hitherto made use of them to construct charts suited to their particular needs.

Consider the equation $x + y = z$. x, y and z being variables. A graphical solution is shown in Fig. 1 where the three parallel axes are equidistant, the two outer being marked off with equal scales representing values of x and y respectively, and the centre axis with a scale having double the value of x or y, i.e., if one unit of length on the x or y axis represents one unit of these variables then one unit of length represents two units of z on the third axis. A straight line such as XZY cutting the axes at those points and swung round about X to the position XZ_1Y_1 will give the increase in the value of z due to increasing y from the value Y to Y_1,

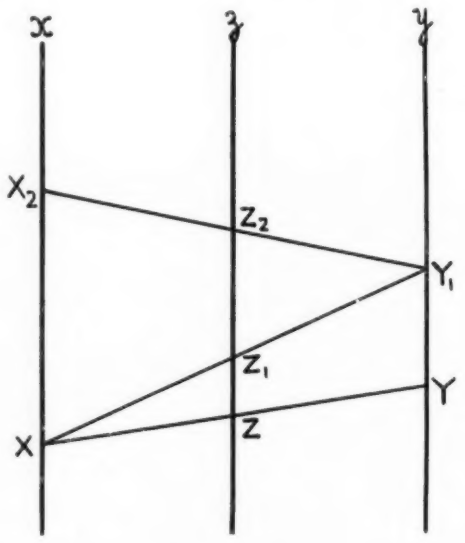


Fig. 1.—Graphical solution of equation $x + y = z$.

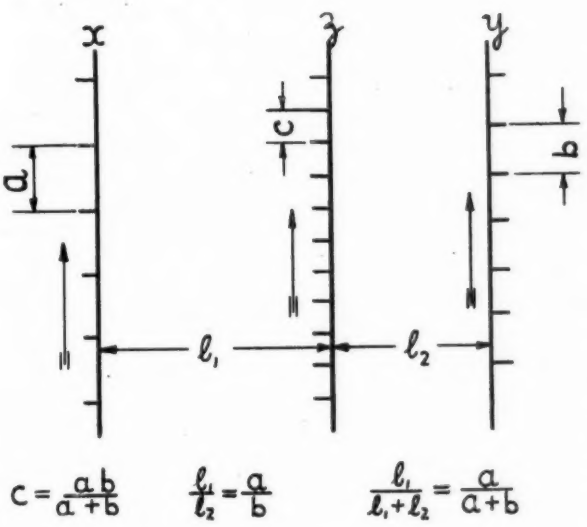


Fig. 2.—Chart representing equation $x + y = z$ (x & y scales in same direction).

e.g., if the increment in y is two units while x remains constant, then the increase in z will also be two units. Similarly if the straight line XZ_1Y_1 be swung about Y_1 to position $X_2Z_2Y_1$, the increment in X from X to X_2 is reflected in the increased value of z from Z_1 to Z_2. Hence it will be seen the movement of the straight line from XY to X_2Y_1 will give directly the corresponding increase in the value of z, from Z to Z_2. In other words any straight line cutting the three axes will show on the centre scale the sum of the readings of the outer axes.

The diagram also enables subtraction to be carried out as it represents the equations $x = z - y$ or $y = z - x$.

The scales may be of any magnitude and run in either direction, but a little consideration will make it clear that the value and direction of two of the scales only may be chosen arbitrarily, the position of the third axis and the direction of its scale then being fixed.

The device as so far described would be of little importance but for the fact that this form of chart may be used for multiplication and division by using logarithmic scales, marked with the ordinary values of x, y and z.

Take the equation $x^a y = z$; this may be written in the form of $a \log x + \log y = \log z$, which can be represented by a nomogram of the type shown in Fig. 1, giving solutions direct, provided that suitable logarithmic scales, marked with the antilogs, are used.

The following rules enable the relative positions and spacing of the axes, together with the directions of the scales, to be determined. The arrangements of axes and directions of scales shown in Figs. 2 and 3 represent the equation $x + y = z$ in each case, but while in Fig. 2 the scales all run in the same direction, in Fig. 3 the x scale runs upwards and the y and z scales downwards. The flexibility given by these alternatives will be found valuable in practical applications as they enable an arrangement to be chosen which will not only give a compact diagram, but will also avoid the possibility of one scale finally turning out to be of such small proportions that accurate readings are impossible. This can very

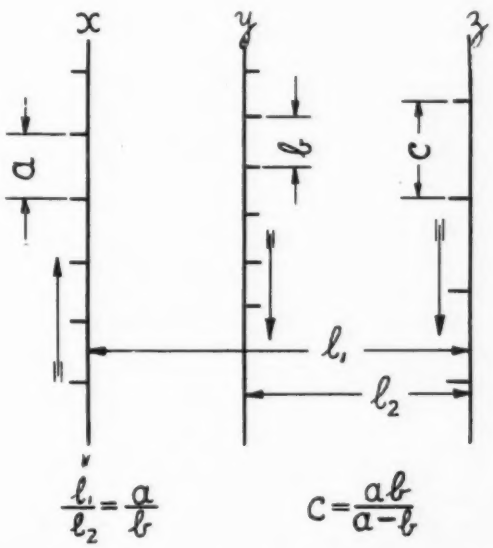


Fig. 3.—Chart representing equation $x + y = z$ (x & y scales in opposite directions).

easily happen, and it is worth while roughing out one or more alternatives before deciding on the final arrangement, and constructing the diagram.

The relative values of the scales, and the spacing of the axes are given for each case in Figs. 2 and 3 where "a" units of length = 1 unit of x, b = 1 unit of y, and c = 1 unit of z.

As regards the relative vertical positions of the scales; as will be realized these may be calculated, but in practice it will be found more convenient to place two of the scales in any desired vertical relation, work out one numerical example, and then fix the vertical position of the third scale on its axis so that the result of the working falls on a straight line drawn through the chosen values of the first and second terms of the equation.

Only equations containing three variables have so far been considered, and it has been shown that nomograms having three axes will give solutions of this class of equation. More than three variables can be dealt with, however, if their number is reduced by combinations of terms and, in effect, combining several three-axis nomograms, each pair having one axis in common. This expedient and also the general methods of construction are best illustrated by a practical example such as, for instance, the formula connecting the torsional stress in a round solid shaft with the power transmitted, the diameter of the shaft, and the R.P.M.

This is :—

$$D^3 = \frac{4.31 \times 10^5 P}{fN}$$

where D = dia. of shaft in inches.
P = Power transmitted in kW.
f = Torsional stress in lb. sq. in.
N = Rev. per min.

Let $\gamma = \dfrac{4.31 \times 10^5 P}{N}$

Then the formula may be rewritten

$$3 \log D = \log \gamma - \log f$$

also $\log (4.31 \times 10^5 P) = \log \gamma + \log N$.

Here are two equations containing three variables each, one of which however is common to the two equations. Two nomograms therefore may be drawn on one sheet, one axis serving for $\log \gamma$ and hence connecting the two portions into which the original formula has been divided. It should be noted, moreover, that as actual values of γ are not required to be known, there is no need to show any scale on this line, the only requirement being that it must be in the correct position relative to the remaining axes. In fact it merely acts as a reference line connecting the two portions of the complete nomogram.

Assuming that the diagram is to embrace values of D from 1 to 20 inches, N from 1,000 to 10,000 r.p.m., and f from 1,000 to 10,000 lb./sq. in., a few trials might lead to the arrangement shown in Fig. 4 which is reasonably spaced, with fairly open scales, and the range of power covered is comprehensive.

The first portion of the nomogram consists of axes for D, γ, and f similarly disposed to x, z and y, Fig. 2. The unit of length in the full size original diagram is the centimetre and the scales and spacing are shown in Fig. 4. It must be noted that while one unit of D, i.e., from log 1.0 to log 10, is represented by 15 centimetres, the actual *scale* of D is one-third of this ($a = 5$) since any point on this line represents 3 log D, i.e., D^3.

Another point to be noted is that, although it is not necessary to show any scale on the γ axis, as values of γ are not required to be read off the diagram, a scale must nevertheless be determined when constructing the diagram, because it must be known in order to calculate the scales and positions of the remaining axes. Also since the γ axis is common to both portions of the diagram, its scale must also be the same, and must be known, in order to construct the second half of the diagram.

A constant multiplying factor may be ignored when constructing a nomogram of the type under consideration, for instance, the constant 4.31×10^5, because the scales being logarithmic the only effect of such a constant is to affect the vertical position of the relevant scale. This influence, of course, is automatically allowed for when fixing the vertical positions by means of a numerical example.

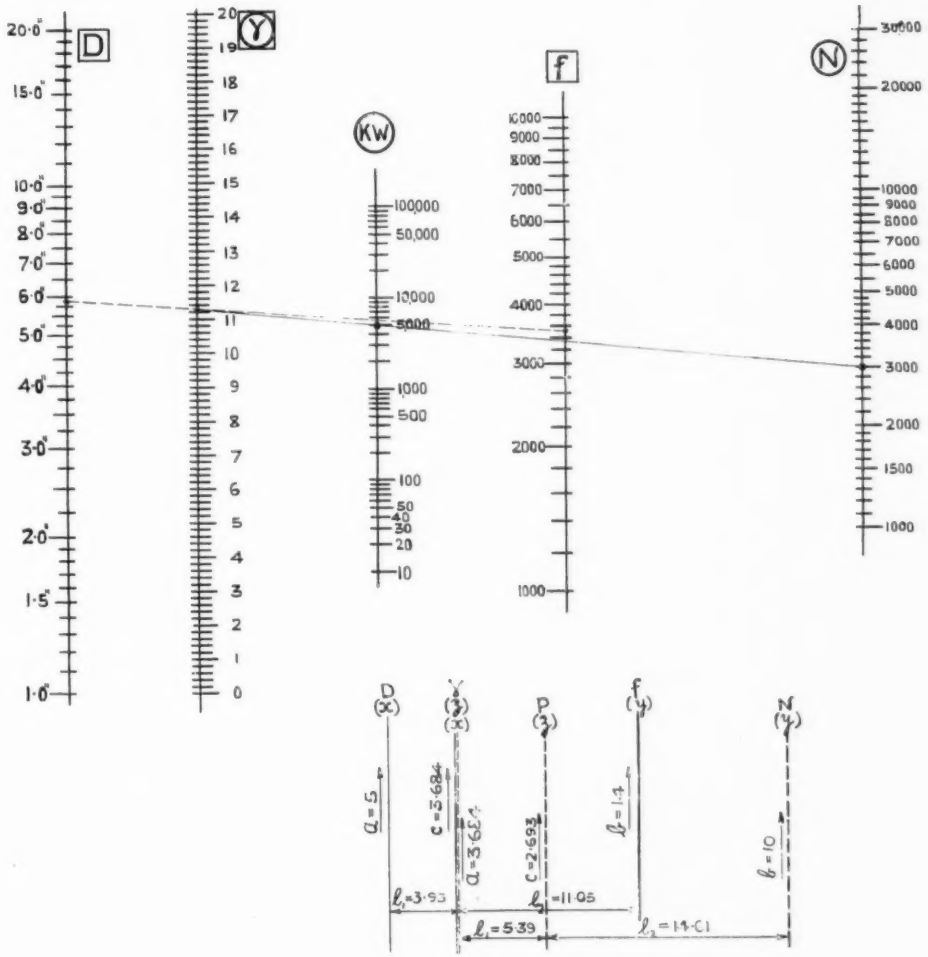


Fig 4.—Nomograms for giving direct readings of the formula connecting the torsional stress in a round solid shaft with the power transmitted, the diameter of the shaft and the r.p.m.

A most important point to be observed when using this class of diagram is that it is not permissible to read from one portion of the nomogram to the other except through the common reference line; for instance, when making use of Fig. 4, rational results will not be obtained if an attempt is made to connect directly the *f* and kW. axes. The axes grouped together in the calculations must be used together, the inter-connection being made through

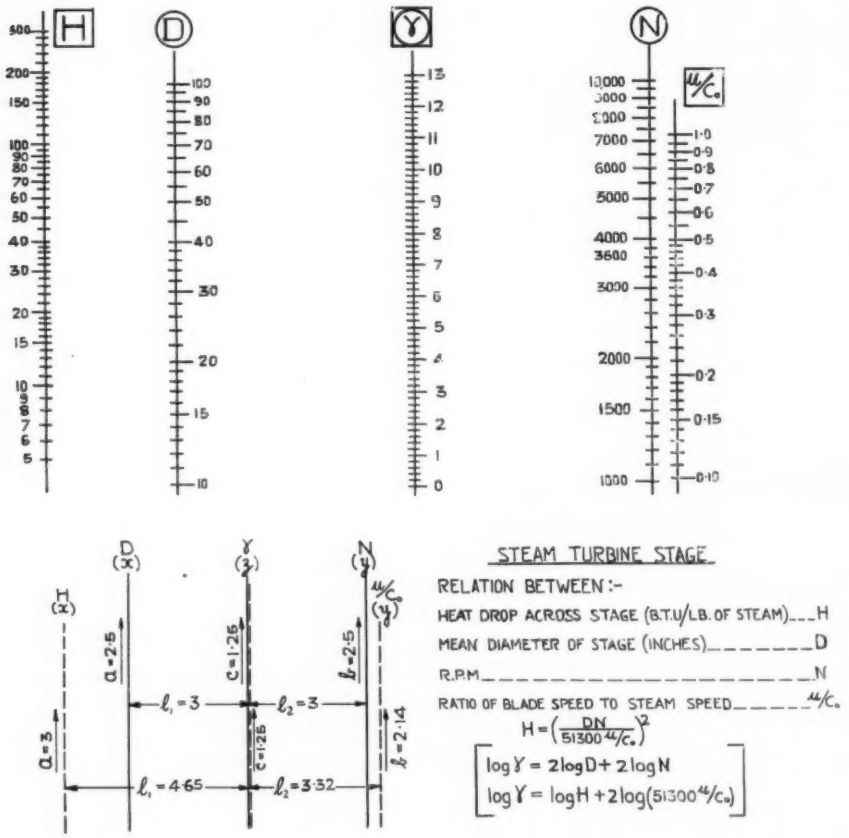


Fig. 5.—Relation between steam and blade speeds in a steam turbine stage.

the common reference line only. One way of ensuring that this stipulation is adhered to is to surround the distinguishing headings of one portion by circles and of the other portion by squares, the heading of the common reference line being inside both a circle and a square. This system has been followed in all the examples shown here.

The markings shown on the reference line are purely arbitrary and have no relation to the scale of γ, but are merely provided to avoid having to pencil mark this axis each time the diagram is used.

Suppose the diameter of a bearing journal is required, which is to transmit 5,000 kW. at 3,000 r.p.m. with a torsional stress of about 3,500 lb./sq. in. The solution of this problem is shown by the cross lines in Fig. 4, the power and r.p.m. being first linked up to give a reading on the reference line. Then a straight line pivoted

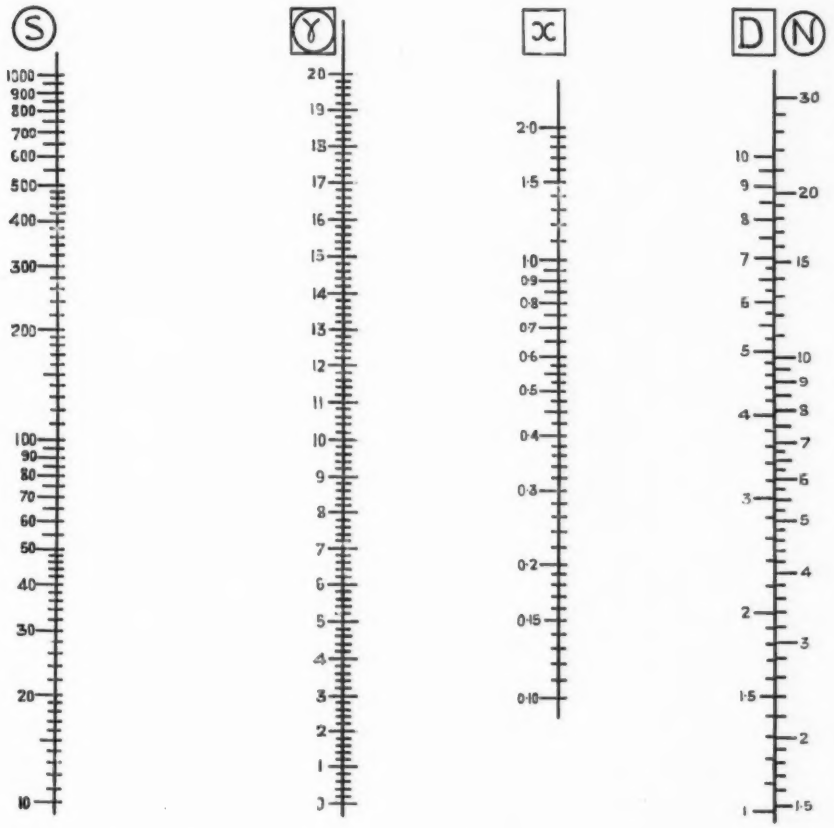


Fig. 6.—Nomogram for Round Wire Springs, where s = stiffness (lbs./inch), x = Wire Diameter (inches), D = Mean Diameter of Coils (inches), N = No. of Active Coils.

about this point, intersecting the stress axis at 3,500 lb./sq. in. and produced to cut the diameter axis, will give the answer $5\frac{7}{8}$ in. diameter. If the last intersecting line be kept in place on the reference line while reading off the diameter, it is a matter of only a second or two to swing the line to the nearest standard size of bearing and read off the stress which that size would have to bear.

Other examples of charts are given in Figs. 5, 6 and 7, and in the case of Fig. 5 the method of construction is shown. They call for no particular comment with the possible exception that Figs. 6 and 7 could be combined on one chart, which however would entail a reduced scale if it were desired to use a standard sized sheet of paper.

Once the various scales have been determined, the most convenient means of marking them out is to use log paper laid at such an angle to the axis that the length log 10 on the paper covers the length log 10 has to occupy on the axis. The intermediate markings can then be projected directly on to the axis.

When using the diagrams it will be found that a line scribed on the underneath surface of a strip

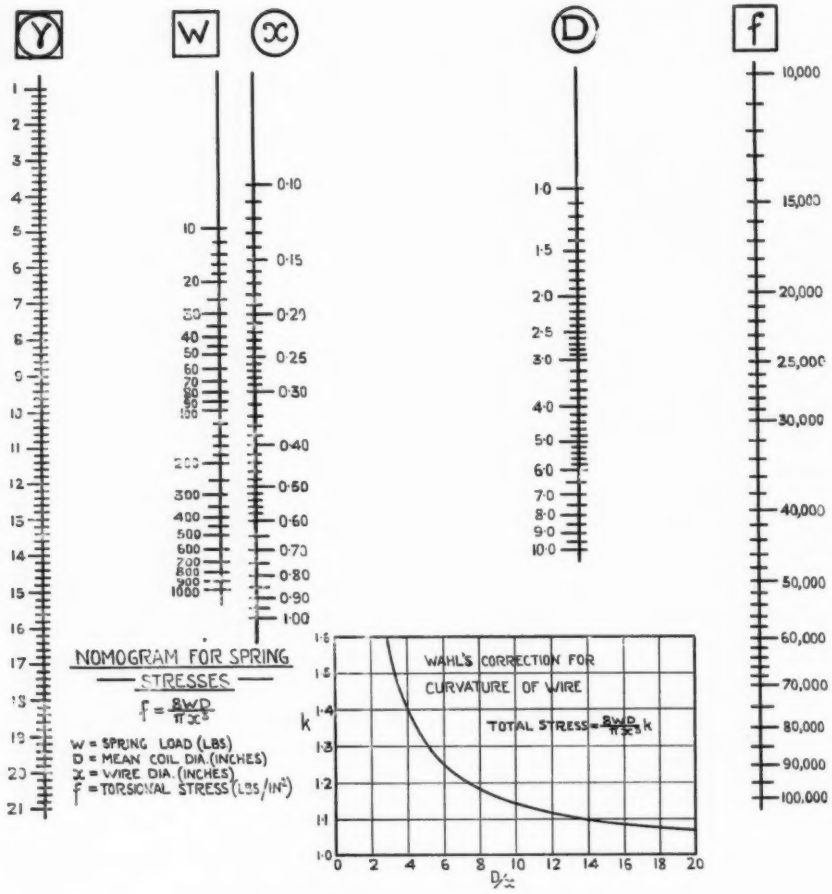
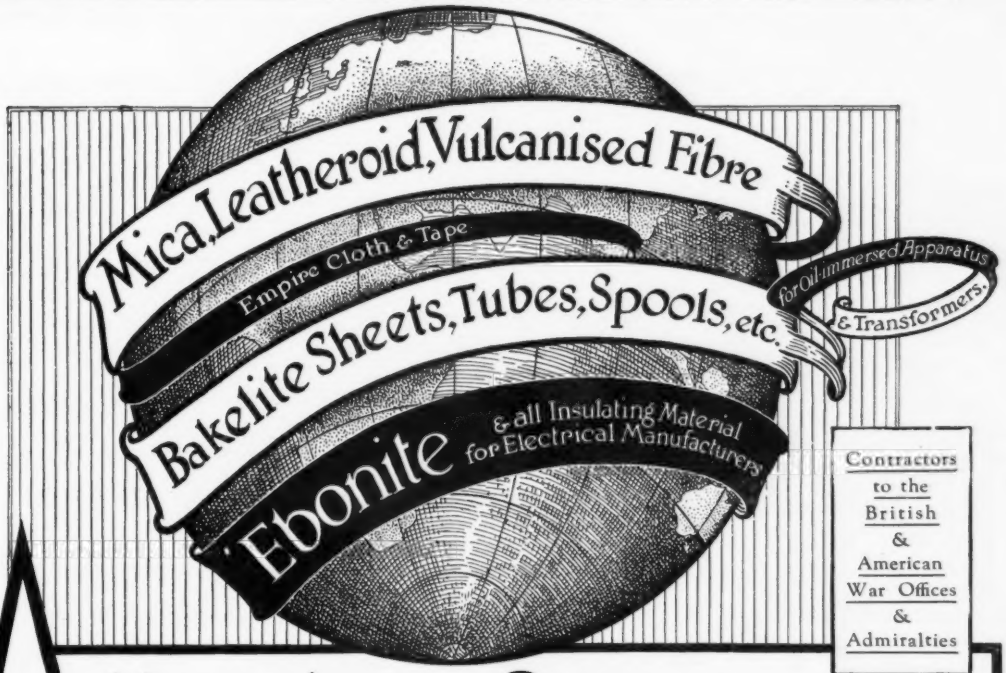


Fig. 7.—Nomogram for Spring Stresses.

of celluloid is easier to read from than a straight edge.

The simple type of nomogram here described will suffice to cover most needs in an engineering design office, but any whose problems demand the use of more complicated forms are referred to "Nomograms in Electrical Engineering," R. O. Kapp, Journal of The Institution of Electrical Engineers, May, 1936, and to The Handbook of Engineering Fundamentals (Eshbach), as two sources of information.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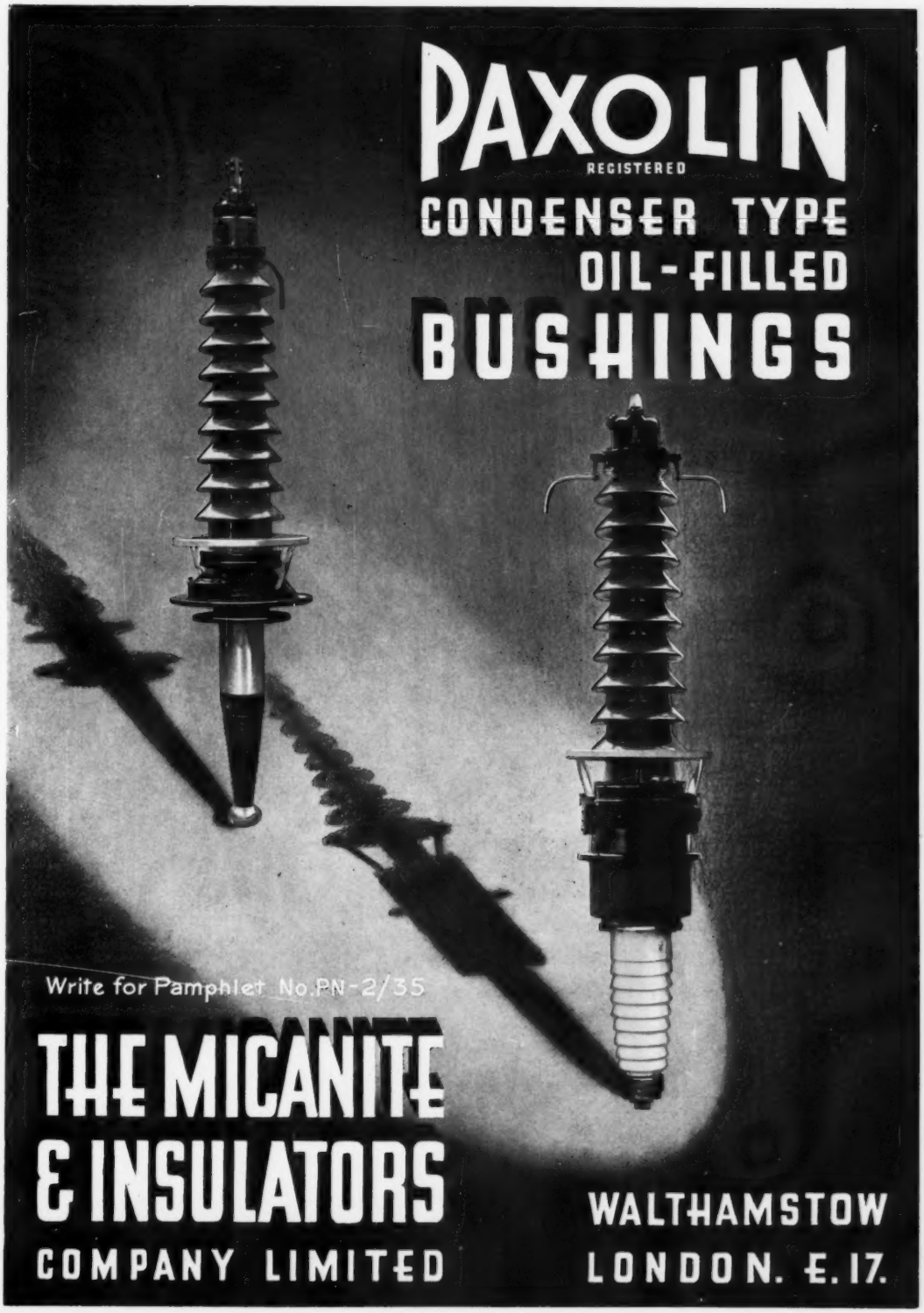
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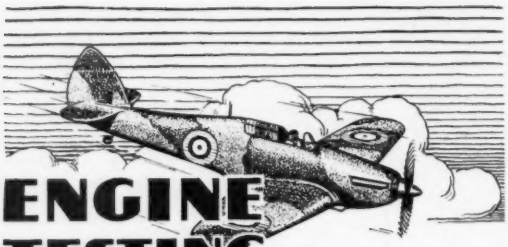

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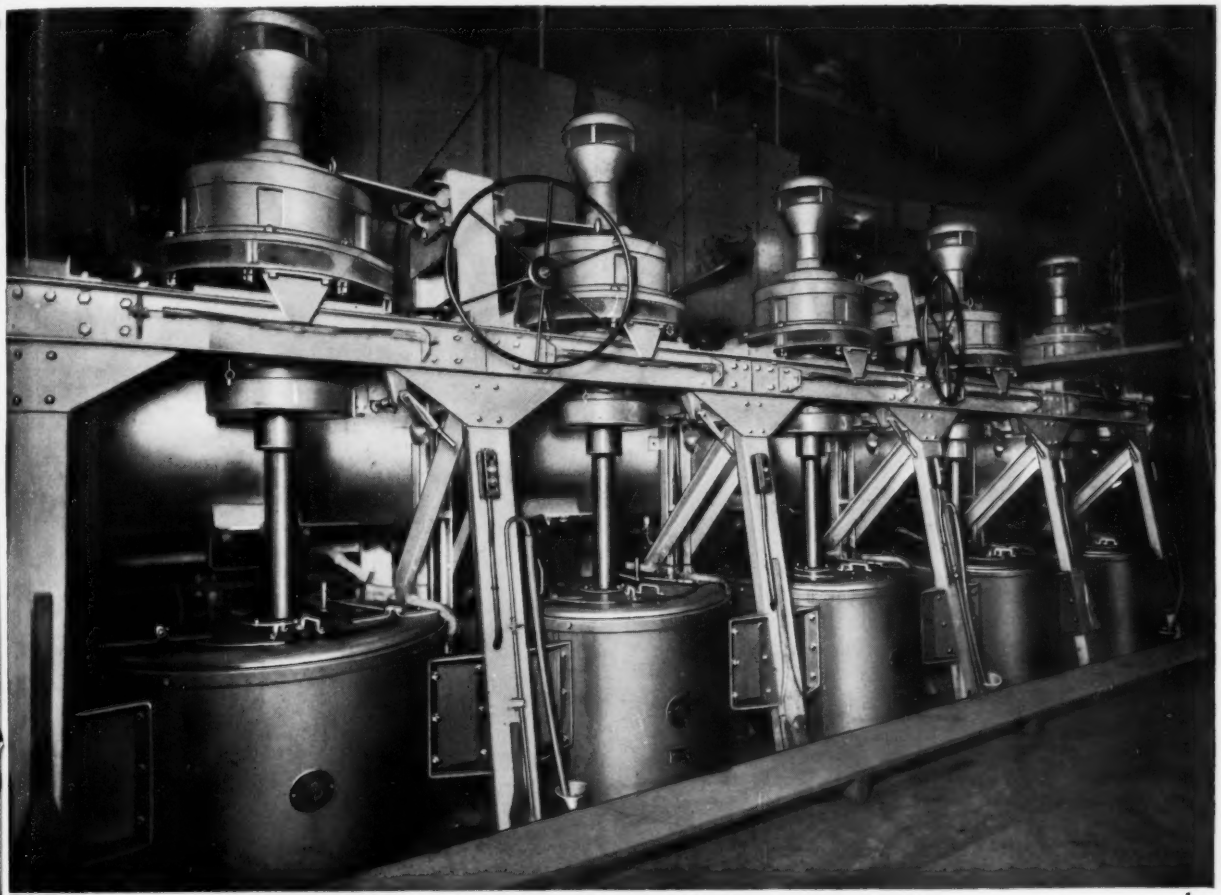

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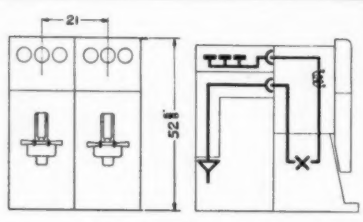

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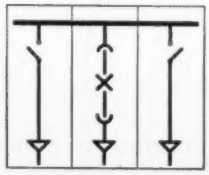

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Associated British Machine Tool Makers, Ltd. XIV

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Attwater & Sons VII

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Bolton, Thomas & Sons Ltd. X

Broadbent, Thos. & Sons, Ltd. XI

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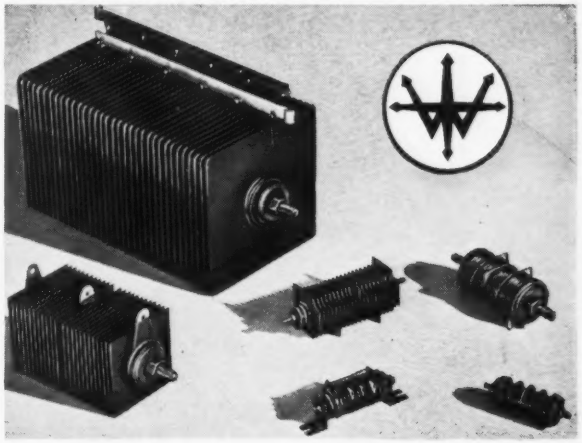

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